Electro-Optic Identification Research Program:
Computer Aided Identification (CAI) and Automatic Target Recognition (ATR)

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LONG-TERM GOALS

The overall goal of the Electro-Optic Identification (EOID) Research Program is to support the performance of EOID sensors transitioning to the fleet. EOID is used in the identification of Mine Like Objects (MLOs) and is a pressing need for Mine Countermeasures (MCM) operations. The EOID sensors include the Streak Tube Imaging LIDAR (STIL), which is transitioning to the AN/AQS-20/X and the WLD-1 (Remote Mine-hunting System) programs, and the Laser Line Scan (LLS), which is transitioning to the AN/AQS-14A(V1) program. Through these transitions, EOID will be a key element in implementation of Fleet plans for a robust organic MCM capability.

The EOID Research Program will begin to provide the tools to meet specific Fleet needs and capabilities, which include:

- Perform mission planning, real-time performance assessment, and post-mission analysis
- Flow down Fleet identification requirements to the system and operational parameters
- Develop Computer Aided Identification (CAI) algorithms to aid in the operator identification of mines
- Develop Autonomous identification capability for future systems
- Assess and evaluate alternate designs for future systems

OBJECTIVES

The primary objective of this phase of the program is to validate existing performance prediction and simulation models and to develop and test Automatic Target Recognition Algorithms (ATR) for electro-optic identification (EOID) systems. In addition, some secondary objectives include:

- Conduct a performance assessment of the existing EOID sensors

Report Documentation Page

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14. ABSTRACT

The overall goal of the Electro-Optic Identification (EOID) Research Program is to support the performance of EOID sensors transitioning to the fleet. EOID is used in the identification of Mine Like Objects (MLOs) and is a pressing need for Mine Countermeasures (MCM) operations. The EOID sensors include the Streak Tube Imaging LIDAR (STIL), which is transitioning to the AN/AQS-20/X and the WLD-1 (Remote Mine-hunting System) programs, and the Laser Line Scan (LLS), which is transitioning to the AN/AQS-14A(V1) program. Through these transitions, EOID will be a key element in implementation of Fleet plans for a robust organic MCM capability.

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- Develop and test the Through the Sensor Environmental Characterization (TSEC) capabilities for EOID sensors
- Develop Real-Time Image Processing Algorithms and Displays (RTIP & D)

APPROACH

To collect the data required for this program, an existing towed body was modified to house the three laser identification systems in one unit to allow simultaneous operations under identical environmental conditions. The three laser identification systems included the Areté Associates Streak Tube Imaging LIDAR (STIL) system, the Northrop Grumman Laser Line Scan (NG-LLS) system, and the Raytheon LLS (R-LLS) system as shown in Figure 1.

Figure 1 Towed Body at the Dock

The system was towed through a field in the Gulf of Mexico off Panama City, Florida comprised primarily of optical targets with some sample mine-like objects while image data from each of the three EOID systems was collected. Ocean optical properties were measured during the test and the operations area was surveyed so that clutter objects were known. This data was then distributed to all participating organizations for use in performance prediction model validation, ATR development, and performance assessment.

The ATR development is divided into two components: detection and classification. The approach to object detection in this effort is based on a local spatial shape-filtered background anomaly scheme. This scheme uses least squares error (LSE) strips to search for background anomalies of certain specified size and shape that stand out from the local background. Once an object has been detected, it is segmented using a two dimensional (2-D) LSE fit on the local background to separate object pixels from background pixels. The object perimeter boundary pixels are then enumerated using customized morphological operations. Finally, basic geometric features are computed (*e.g.*, object centroid, length, width, area, and orientation).

A classification scheme, based on Zernike moments and neural networks, is being developed by Dr. Mahmood Azimi at Colorado State University. This classifier will use the CSS detection outputs to generate Zernike moment based features that will be utilized in a nearest neighbor neural network for final classification.

A data analysis/browsing tool developed under CAI/ATR task is a graphical user interface (GUI) modification of a previous analysis/browsing tool developed under the FY00 Coastal Benthic Optical Properties (CoBOP) program. The modified GUI analysis/browser tool was developed for quick and easy browsing of data from all three of the EOID sensors following each day's data collection operations and for support of ATR/CAI development.

WORK COMPLETED

Modifications were made to the towed body for acceptance of the three EOID sensors that were subsequently integrated into the towed body system. Data collection was conducted in the Gulf of Mexico off of Panama City, Florida in approximately 60-70 feet of water. Data was collected from a target field about 300 feet in length consisting of 24 technical targets, 12 Mine-like objects, clutter, and a 12-foot stepladder. Data collection operations were conducted over a two-week period and consisted of multiple passes per day over the same target field at varying altitudes that were based on optical property measurements taken before the start of each day. Data was collected in both day and nighttime conditions at speeds between 5 and 10 knots. Daily, data were archived, processed and browsed to determine utility.

This year, the object detection routine developed for laser line scan (contrast) images was nearly completed. Initial detection and segmentation routines were developed using downsized contrast images giving object centroid, length, width, and orientation, as shown in Figure 1. Nonmine-like objects will be thresholded based on simple area and length/width ratio features for final mine-like detection using full resolution data. The final detection algorithm can be directly used on range imagery with little modification. Contrast and range detections will be applied separately and then merged together in a fuzzy logic scheme for final detection for STIL data.

Figure 2 . Enhanced image (left), detected image (middle), and detected and segmented image (right) for a laser line scan image. The object length, width, area and orientation is computed at this point.

The contract for Dr. Azimi for classification was placed in late September so the primary work will take place in FY02.

The data analysis/browser tool was converted to a GUI version with its browsing capabilities functional and was heavily utilized during the August field test. This tool allowed the large amount of EOID data collected from all three sensors to be quickly and easily viewed to support the field test.

RESULTS

The EOID Gulf of Mexico Test provided the data required for model validation with a small set useful for ATR development. All three sensors were successfully deployed and operated in one underwater TB and testing verified that the sensors operated functionally under towing conditions. Initial results from browsing the data showed that each sensor performed optimally based on the altitude and water conditions. Data was successfully captured for seven full days and two partial days of data collection under a variety of altitudes and environmental conditions. Some optical cross-talk was noted; however, post-mission processing proved sufficient to remove these effects.

The object detection scheme, which can be applied to both contrast and range imagery, was nearly completed and consists of image pre-processing (image enhancement), anomaly filtering and detection, binary thresholding and segmentation, and basic geometric feature computation. The image pre-processing uses an automated image enhancement routine that was developed under a previous program. This routine essentially corrects uneven signal strength illumination and maximizes image contrast. Another routine has been developed and will be explored that is less intensive and reduces image artifact but does not effectively correct uneven signal strength illumination in the forward direction.

Routines were developed for background anomaly filtering and detection and provides for the core of the detection routine. The anomaly background image is generated by filtering pixels that stick out from the local background within strips of specified size. This is accomplished by comparing the difference between the LSE fit using 1-D background strips to the actual values. A best fit is achieved by taking the difference value of the smallest error of the LSE fit for four orientations (0, 45, 90, and 135 degrees). A second filter is applied on the anomaly background image by summing pixels within 2-D regions of specified shape and size. Object detection is then obtained by thresholding this second filtered image for peak values resulting in an initial centroid and orientation for the object. Orientation is determined by the minimal LSE error of the four orientations used.

A routine was developed, using the initial centroid and orientation of the object, which computes a 2-D LSE fit of the local background sufficiently away from the object. This background fit is then used to threshold the entire local region (both background and target regions) into either object pixels or background pixels. Segmentation is accomplished by identifying object perimeter pixels on or near the object centroid and filling in interior points. The object final centroid and initial orientation is computed using second moments on the segmented object. A more accurate orientation, along with the object length and width, is computed from a best-fit line extending along the length of the object.

Image processing algorithms that were developed for the Raytheon LLS sensor were modified for both the Northrop Grumman LLS sensor and the Arete STIL sensor. These algorithms could be directly used for the NG-LLS but not for STIL. The LLS line effect correction routine (line facet correction) could not be used for the STIL line jitter effect since the jitter effect is not periodic and thus an alternative method was developed. Also, the CSS automated image enhancement routine cannot be used directly because of the CCD array effects in the STIL data. CSS did develop an automated image enhancement that could be effectively used for all three sensors differing only with correction of

sensor specific noise or artifacts. This includes jitter effect and CCD array effect correction (reduction) for STIL, and LLS line effect and cross-talk noise for the two LLS sensors. The general enhancement routine developed for the three sensors includes noise (artifact) correction, log scale enhancement and linear stretching to full dynamic range, and a shading effect correction for altitude correction in the cross-track direction. Figure 3 shows the cross-talk removal and enhancement for an NG-LLS image.

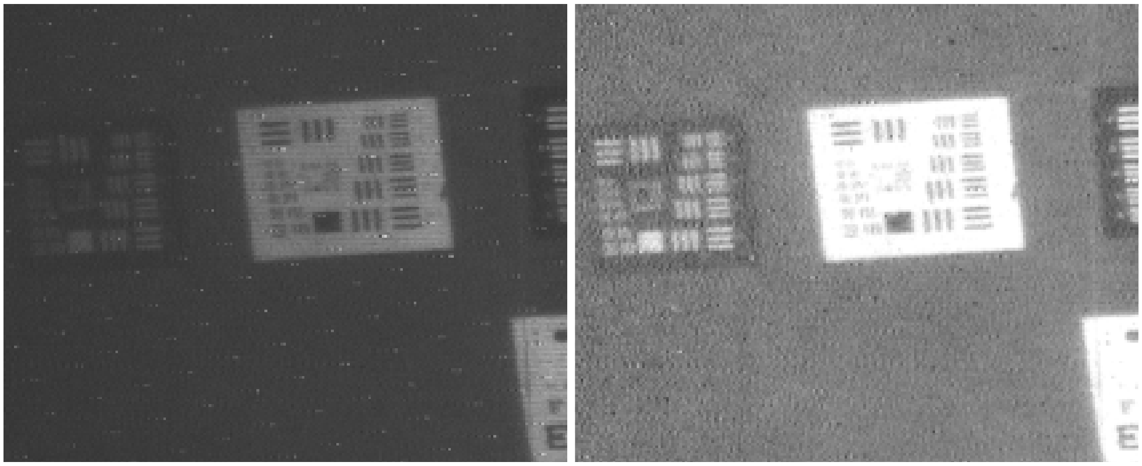

Figure 3 An example of a raw NG-LLS image, linearly stretched for display, (left) and its automated enhancement (right) under turbid conditions

IMPACT/APPLICATIONS

One of the goals of the program is the development of CAI/ATR routines for use in the Fleet EOID systems to speed identification of mines. The approach taken here shows considerable potential for resolving this need for the AN/AQS-20/X, WLD-1, and AN/AQS-14A(V1) programs.

TRANSITIONS

Of more immediate impact, however, was the additional operating time logged by the sensors under very stressing conditions. The system developers saw water clarity conditions that have not been encountered – or considered – in earlier efforts. These conditions had some unpleasant consequences for post-mission processing routines in particular and forced a re-evaluation of environmental impact. All system developers also learned much about the strengths and weaknesses of their particular sensor and have begun looking at options for improvement.

RELATED PROJECTS

The detection routine developed under this task was leveraged from the CSS FY01 independent laboratory in-house (ILIR) research project *Underwater Electro-optic Image Processing Task*. In addition, data collected here is being made available to the Program Executive Office for Mine and Undersea Warfare (PEO(MUW)) for their use in system development.

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Model Validation Plan, 30 July 2001.

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